Mystery minerals formed in fireball from colliding asteroid that destroyed the dinosaurs

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Scientists at the American Museum of Natural History and the University of Chicago have explained how a globe-encircling residue formed in the aftermath of the asteroid impact that triggered the extinction of the dinosaurs. The study, which will be published in the April issue of the journal Geology, draws the most detailed picture yet of the complicated chemistry of the fireball produced in the impact. The residue consists of sand-sized droplets of hot liquid that condensed from the vapor cloud produced by an impacting asteroid 65 million years ago. Scientists have proposed three different origins for these droplets, which scientists call "spherules." Some researchers have theorized that atmospheric friction melted the droplets off the asteroid as it approached Earth's surface. Still others suggested that the droplets splashed out of the Chicxulub impact crater off the coast of Mexico's Yucatan Peninsula following the asteroid's collision with Earth.

But analyses conducted by Denton Ebel, Assistant Curator of Meteorites at the American Museum of Natural History, and Lawrence Grossman, Professor in Geophysical Sciences at the University of Chicago, provide new evidence for the third proposal. According to their research, the droplets must have condensed from the cooling vapor cloud that girdled the Earth following the impact.

Ebel and Grossman base their conclusions on a study of spinel, a mineral rich in magnesium, iron and nickel contained within the droplets.

"Their paper is an important advance in understanding how these impact spherules form," said Frank Kyte, adjunct associate professor of geochemistry at the University of California, Los Angeles. "It shows that the spinels can form within the impact plume, which some researchers argued was not possible."

When the asteroid struck approximately 65 million years ago, it rapidly released an enormous amount of energy, creating a fireball that rose far into the stratosphere. "This giant impact not only crushes the rock and melts the rock, but a lot of the rock vaporizes," Grossman said. "That vapor is very hot and expands outward from the point of impact, cooling and expanding as it goes. As it cools the vapor condenses as little droplets and rains out over the whole Earth."

This rain of molten droplets then settled to the ground, where water and time altered the glassy spherules into the clay layer that marks the boundary between the Cretaceous and Tertiary (now officially called the Paleogene) periods. This boundary marks the extinction of the dinosaurs and many other species.

The work that led to Ebel and Grossman's Geology paper was triggered by a talk the latter attended at a scientific meeting approximately 10 years ago. At this talk, a scientist stated that spinels from the Cretaceous-Paleogene boundary layer could not have condensed from the impact vapor cloud because of their highly oxidized iron content. "I thought that was a strange argument," Grossman said. "About half the atoms of just about any rock you can find are oxygen," he said, providing an avenue for extensive oxidation.

Grossman's laboratory, where Ebel worked at the time, specializes in analyzing meteorites that have accumulated minerals condensed from the gas cloud that formed the sun 4.5 billion years ago. Together they decided to apply their experience in performing computer simulations of the condensation of minerals from the gas cloud that formed the solar system to the problem of the Cretaceous-Paleogene spinels.

UCLA's Kyte, who himself favored a fireball origin for the spinels, has measured the chemical composition of hundreds of spinel samples from around the world.

Ebel and Grossman built on on Kyte's work and on previous calculations done by Jay Melosh at the University of Arizona and Elisabetta Pierazzo of the Planetary Science Institute in Tucson, Ariz., showing how the asteroid's angle of impact would have affected the chemical composition of the fireball. Vertical impacts contribute more of the asteroid and deeper rocks to the vapor, while impacts at lower angles vaporize shallower rocks at the impact site.

Ebel and Grossman also drew upon the work of the University of Chicago's Mark Ghiorso and the University of Washington's Richard Sack, who have developed computer simulations that describe how minerals change under high temperatures.

The resulting computer simulations developed by Ebel and Grossman show how rock vaporized in the impact would condense as the fireball cooled from temperatures that reached tens of thousands of degrees. The simulations paint a picture of global skies filled with a bizarre rain of a calcium-rich, silicate liquid, reflecting the chemical content of the rocks around the Chicxulub impact crater.

Their calculations told them what the composition of the spinels should be, based on the composition of both the asteroid and the bedrock at the impact site in Mexico. The results closely matched the composition of spinels found at the Cretaceous-Paleogene boundary around the world that UCLA's Kyte and his associates have measured.

Scientists had already known that the spinels found at the boundary layer in the Atlantic Ocean distinctly differed in composition from those found in the Pacific Ocean. "The spinels that are found at the Cretaceous-Paleogene boundary in the Atlantic formed at a hotter, earlier stage than the ones in the Pacific, which formed at a later, cooler stage in this big cloud of material that circled the Earth," Ebel said.

The event would have dwarfed the enormous volcanic eruptions of Krakatoa and Mount St. Helens, Ebel said. "These kinds of things are just very difficult to imagine," he said.

The results in this paper strengthen the link between the unique Chicxulub impact and the stratigraphic boundary marking the mass extinction 65 million years ago that ended the Age of Dinosaurs. The topic will be explored further in a new groundbreaking exhibition, "Dinosaurs: Ancient Fossils, New Discoveries," set to open at the American Museum of Natural History on May 14. After it closes in the New York, the exhibition will travel to the Houston Museum of Natural Science (March 3-July 30, 2006); the California Academy of Sciences, San Francisco (Sept. 15, 2006-Feb. 4, 2007); The Field Museum, Chicago (March 30-Sept. 3, 2007); and the North Carolina State Museum of Natural Sciences, Raleigh (Oct. 26, 2007-July 5, 2008).

Source: Geological Society of America